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(54) Ring tube CT scanner

CT Scanner mit ringförmiger Röhre

Scanner CT avec tube annulaire

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Description

The present invention pertains to the art of diagnostic imaging. It finds particular application in conjunction with CT scanners for generating images of interior regions of human patients and will be described with particular reference thereto. However, it is to be appreciated, that the present invention will also find application in conjunction with industrial CT, quality assurance, and other types of x-ray diagnostic imaging, x-ray generation applications, and the like.

Typically, a patient is positioned in a prone position on a horizontal couch through a central bore of a CT scanner. An x-ray tube mounted on a rotatable gantry portion is rotated around the patient at a high rate of speed. For faster scans, the x-ray tube is rotated more quickly. However, rotating the x-ray tube more quickly decreases the net radiation per image unless the x-ray output of the x-ray tube is increased. As CT scanners have become faster, larger x-ray tubes which generate more radiation per unit time have been required. The high gantry rotational speeds, of course, cause high inertial forces during rotation.

High performance x-ray tubes for CT scanners and the like commonly include a stationary cathode and a rotating anode disk, both enclosed within an evacuated housing. When higher intensity x-ray beams are generated, there is more heating of the anode disk. In order to provide sufficient time for the anode disk to cool by radiating heat through the vacuum to surrounding fluids, x-ray tubes with progressively larger anode disks have been built.

The larger anode disks require larger x-ray tubes which do not readily fit in the small confined spaces of existing CT scanner gantries. In a fourth generation scanner, the incorporation of a larger x-ray tube and heavier duty support structure requires moving the radiation detectors to a larger diameter. If the distance from the x-ray focal spot to the collimator is too short, the x-ray penumbra and beam divergence cause a degradation in image quality. Not only is a larger x-ray tube required, larger heat exchange structures are required to remove the larger amount of heat which is generated. Thus, as the CT scanners have become faster, they have become more massive, hence more difficult to move and install.

Rather than rotating a single x-ray tube around the subject, others have proposed using a switchable array of x-ray tubes, e.g. five or six x-ray tubes in a ring around the subject. However, unless the tubes rotate only limited data is generated and only limited image resolution is achieved. If the x-ray tubes rotate, similar mechanical problems are encountered trying to move all the tubes quickly.

Still others have proposed constructing an essentially bell-shaped, evacuated x-ray tube envelope with a mouth that is sufficiently large that the patient can be received in the well of the tube. An x-ray beam source is disposed at the apex of the bell to generate an electron beam which impinges on an anode ring at the mouth to the bell. Electronics are provided for scanning the x-ray beam around the evacuated bell-shaped envelope. One problem with this design is that it is only capable of scanning about 210°. Another problem is that the very large evacuated space required for containing the scanning electron beam is difficult to maintain in an evacuated state. Troublesome and complex vacuum pumping systems are required. Another problem is that no provision can be made for off-focus radiation. Another problem resides in its large physical size.

Messrs. Mayden, Shepp, and Cho in "A New Design For High-Speed Computerized Tomography", IEEE Transactions on Nuclear Science, Vol. NS-26, No. 2, April 1979, proposed reducing the size of the conical or bell-shaped tube discussed above by rotating the cathode around the large diameter anode ring. However, their design had several engineering deficiencies and was not commercially produced.

US-A-4227088 discloses an x-ray generation and detection apparatus for use in a computer assisted tomography system which permits relatively high speed scanning. A large x-ray tube having a circular anode surrounds the patient area. A movable electron gun orbits adjacent to the anode. The anode directs into the patient area x-rays which are delimited into a fan beam by a pair of collimating rings. After passing through the patient, x-rays are detected by an array of movable detectors. Detector subarrays are synchronously movable out of the x-ray plane to permit the passage of the fan beam.

The present invention contemplates a new and improved CT scanner which overcomes the above-referenced problems and others.

According to the invention there is provided a CT scanner comprising:

a generally toroidal x-ray tube defining a central bore of sufficient diameter for passing an imaged region of a subject therethrough, the toroidal x-ray tube generating a generally fan-shaped x-ray beam from a multiplicity of locations there around, which x-ray beam is directed across the central bore from an apex location in the x-ray tube, said x-ray tube including a generally toroidal housing having an evacuated interior, an annular anode surface mounted within the toroidal housing interior, a cathode assembly disposed within the toroidal housing including a means for emitting electrons to form an electron beam that strides the anode surface, and a means for moving the electron beam to at least a multiplicity of points around the anode surface;

an x-ray tube mounting means for mounting the toroidal x-ray tube;

a radiation detection means including an arc of radiation detectors spanning an arc for detecting the x-ray beam after it is passed through the imaged sub-

ject region in the bore;

an x-ray beam apex location determining means for determining an angular position of the x-ray beam apex location; and

an image reconstruction means operatively connected with the radiation detection means and the x-ray beam apex location determining means for reconstructing an image representation of the image region of the subject,

characterized in that the radiation detection means includes:

a rotatable mounting means for mounting the arc of radiation detectors for rotation around the bore of the toroidal x-ray tube;

a detector arc rotating means for rotating the detector arc around the bore; and

a detector rotation control means operatively connected with at least the x-ray beam apex location determining means for controlling the detector arc rotating means such that the detector arc is maintained generally opposite to the determined apex location.

The anode surface may be a single, continuous annulus or can be assembled from a plurality of segments. The cathode assembly of the x-ray tube is rotatably mounted within the toroidal housing. The means for moving the electron beams includes a means for rotating the cathode assembly. A compensator and a collimator are mounted for rotation with the cathode assembly and the x-ray source.

The cathode assembly includes a multiplicity of electron emitting means arranged in an annular ring within the housing. The electron beam moving means includes means for selectively causing each of the electron emitting means to emit a beam of electrons which impact the anode surface to generate the x-ray beam. The housing defines an annular window facing toward a central axis of the bore. An annular shutter member is disposable across the window for blocking the emission of x-rays therefrom. A shutter moving means selectively moves the shutter member into and out of the x-ray blocking relationship with the window.

The x-ray beam apex location determining means includes

a laser gyro for monitoring an angular position of the rotatable cathode assembly.

The radiation detection means includes a plurality of scintillation crystals which are rotatably mounted to the toroidal x-ray tube for rotation around the central bore. A ring of opto-electrical transducers are stationarily mounted adjacent the toroidal housing in optical communication with the scintillation crystals. In this manner, a corresponding fraction of the opto-electrical transducers are coupled in an optical communication with the scintillation crystal arc. Means is provided for controlling the electron emitting means such that the generated beam of x-rays has one of at least two selectable different energies.

A plurality of voltage sources are connected in parallel with relatively high potential between the electron emitting mess and the anode surface. There is a sufficiently low plurality of voltage sources that even if one voltage source should fail, the remaining voltage sources provide the high potential between the electron emitting means and the anode surface such that a useful x-ray beam current continues to be generated.

The x-ray tube mounting means includes a mess selectively rotating the toroidal x-ray tube relative to a horizontal axis and a means for selectively translating the toroidal x-ray tube vertically. In this manner, the CT scanner is adapted to reconstructing an image representation of an imaged region of a standing subject.

One advantage of the present invention resides in its high x-ray power density.

Another advantage of the present invention resides in its lighter weight and manufacturing simplicity.

Another advantage of the present invention resides in its high scanning speeds.

Another advantage of the present invention resides in long tube life, augmented by ready field repair ability.

The invention will now be described by way of example with reference to the accompanying drawings in which:-

FIGURE 1 is a perspective view of a CT scanner not covered by the present invention but useful for its understanding;

FIGURE 2 is a transverse, cross-sectional view of the x-ray source and radiation detector portion of the CT scanner of FIGURE 1;

FIGURE 3 is a transverse section of an alternate embodiment of the x-ray ring tube with a stationary cathode assembly;

FIGURE 4 is a front view in partial section with associated electronics of the ring tube of FIGURE 3;

FIGURE 5 is a perspective view of one of the cathode cups of FIGURES 3 and 4 with associated electronics;

FIGURE 6 is a transverse cross-sectional view of a CT scanner tube not covered by the present invention but useful for its understanding; in which a ring of non-rotating x-ray detectors nutates into a plane of the x-ray beam;

FIGURE 7 is an alternate embodiment of a CT scanner not covered by the present invention but useful for its understanding;

FIGURE 8 is a transverse sectional view of an alternate embodiment of the x-ray generating and detecting portion of a third generation CT scanner in accordance with the present invention; and

FIGURE 9 is a transverse sectional view of another

alternate embodiment of a third generation type CT scanner in accordance with the present invention.

With reference to FIGURE 1, a CT scanner includes a toroidal ring x-ray tube I which is mounted on a mounting means or assembly II. An electronic section III provides operating power and control signals to the ring tube and the mounting assembly II and receives data therefrom to reconstruct into an electronic image representation.

With continuing reference to FIGURE 1 and further reference to FIGURE 2, the ring tube I includes a toroidal housing A which defines a large, generally donut-shaped interior volume. An anode **B** is mounted within the toroidal housing interior volume and extends circumferentially therearound. A cathode means **C** is disposed within the toroidal housing interior space for generating at least one beam of electrons. A means **D** selectively rotates the electron beam around the anode **B**.

More specifically, the anode **B** is a tungsten toroid having a tungsten face **10** upon which the electron beam impinges. The housing and the anode define an annular cooling fluid path or channel **12** in intimate thermal communication with the anode face, specifically along an opposite surface of the anode. The anode can be a large continuous member or assembled form multiple sections. Optionally, the anode can have internal passages, fins, and the like to promote thermal communication with the cooling fluid. A fluid circulating means **14** circulates the fluid through the stationary anode and housing to a heat exchanger **16** to keep the target anode cool.

A window **20** is defined in the housing closely adjacent to the target anode **B**. The window is positioned such that an x-ray beam **22** generated by interaction of the electron beam and the tungsten target anode is directed transverse to a central axis **24** of the toroidal tube through a central bore **26**. Preferably, the window is constructed of a sheet of stainless steel which is TIG welded in a vacuum sealed relationship to preferably steel surrounding portions of the toroidal housing **A**. Preferably, the housing at least adjacent to the anode is constructed of beryllium to reduce the intensity of off-focal radiation. A vacuum means, preferably one or more ion pumps **28**, is interconnected with the housing to maintain the vacuum within the housing.

In the embodiment of FIGURES 1 and 2, the cathode assembly includes an annular ring **30** which extends around the interior of the toroidal housing. One or more cathode cups **32** are mounted on the cathode ring. The cathode cups **32** each includes a cathode filament **34**.

In the preferred embodiment, each of the cathode cups **32** has a preselected focus characteristic. In this manner, different dimensions of the x-ray beam focal spot are chosen by selecting among the cathode cups. Optionally, there are multiple cathode cups focused with the most commonly used dimensions to provide a back-up cathode cup in the event the first cathode cup should burn out.

The cathode ring **30** is rotatably supported within the housing by a bearing means **40**. In the preferred embodiment, the bearing means is a magnetic levitation bearing. Thin rings **42** of silicon iron or other material, suitably prepared to be insulating in vacuum, are longitudinally stacked to form cylinders for the radial portion of the bearing. Thin hoops of silicon iron or other material, also suitably prepared for use in vacuum, are assembled to form tightly nested cylinders for the axial portion of the bearing. Passive and active elements, i.e. permanent magnets **44** and electromagnets **46**, are controlled by proximity sensors and suitable feedback circuits to balance attractive forces and suspend the cathode ring accurately in the center of the toroidal vacuum space and to center the cathode ring axially. A brushless, large diameter induction motor **50** includes a stator **52** stationarily mounted to the housing and a rotor **54** connected with the cathode ring. The motor causes the cathode assembly **C** to rotate at a selected speed through the toroidal vacuum of the housing. Mechanical roller bearings **56** are provided for supporting the cathode ring in the event the magnetic levitation system should fail. The mechanical roller bearings prevent the cathode ring from interacting with stationary housing and other structures. A laser gyro or other angular position monitoring means **58** monitors the angular position of the cathode assembly, hence the location of the apex of the x-ray beam on the anode surface.

Adjacent each cathode cup assembly **32**, there is a support **60** which rotates with the cathode cup. The support **60** carries a filter or compensator **62** which is mounted to the support adjacent to the window for filtering the generated x-ray beams to provide beam hardness correction or the like. Preferably, the filter is a shaped block of beryllium oxide (BeO). Optionally, structures for defining fan beam angle or width may also be mounted for rotation with the cathode cup.

A current source **70** provides an AC current for actuating the selected cathode cup. The AC current is passed to a stationary, annular capacitor plate **72** mounted inside the housing. A matching, rotating capacitor plate **74** supported by the cathode ring is mounted closely adjacent to the stationary cathode plate. The rotating cathode plate is electrically connected with a series of magnetically controlled switches **76**. Each of the switches **76** is connected by an isolation transformer **77** with one of the cathode cups or circuitry for controlling a bias to any grids on the cathode cups. A plurality of annular electromagnets **78** are stationarily mounted along the housing. An electrical control means **80** on an operator control **82** permits actuation of one or more of the electromagnets for opening and closing the magnetically controlled switches to select among the cathode cups and any biasing potentials.

The isolation transformer **77** includes a primary

winding **83** connected with the switch **76** and the annular ring **30**. A secondary **84** is connected with one end of the cathode filament **34** and a high voltage supply line **85** which biases the cathode cup to -100 to -200 kV. A ceramic insulator **86** insulates the annular ring **30** from the cathode cup and the high voltage supply line **85**. A filament **87** that is connected between the annular ring **30** and the current source **70** boils off electrons that are transferred to the housing. This transfers any charge accumulated on the annular ring and holds the housing and annular ring at the same potential.

Alternately, external switches provide power to one of a plurality of stationary capacitor rings. Each of a matching plurality of rotating rings is connected with a different cathode cup. As yet another alternative, the capacitive coupling may be replaced by an inductive coupling, such as a stationary annular primary winding which is mounted closely and adjacent and across an air gap from the rotating annular secondary winding.

The anode and the cathode are maintained at a high relative voltage differential, typically on the order of 130 kV. In the preferred embodiment, the stationary housing and the anode are held at ground, for user safety. The rotating cathode assembly is biased on the order of -130 kV relative to the housing. To this end, a high voltage section **90** generates a high voltage which is applied to a hot cathode **92** of a vacuum diode assembly. The hot cathode filament **92** is preferably of a low work function type.

Preferably, the high voltage section **90** is a multiplicity of compact, three phase, high-frequency voltage generators $\mathbf{90_1}$, $\mathbf{90_2}$, ... $\mathbf{90_n}$ connected with parallel current sharing outputs. In this manner, should one of the power supplies fail, the remaining power supplies operated in parallel maintain an adequate x-ray current albeit at a reduced mA such that the CT scanner is still operable at a lower energy level. Each generator has a minimal output capacitance to minimize energy storage and reduce damage if arcing should occur. The low capacitance also enables higher speed kV switching for dual energy applications. To reduce peak power demands from the electrical system of the medical facility, the voltage generators **90** are connected with an energy storage device **93**, such as storage batteries or capacitors. The energy storage device draws current to recharge at a relatively low rate and supplies current at a relatively high rate during an exposure.

A circular channel of a toroidal or donut-shaped plate **94** partially surrounds the hot cathode filament. The toroidal plate is mounted to the cathode assembly for rotation therewith. Preferably, a ceramic or other thermally isolating plate or means **96** isolates the toroidal plate from the rotating annular ring **30**. The current is conducted by the high voltage supply line **85** from the toroidal plate to the cathode cup. The supply line **85** is preferably a thin wire or film to limit heat transfer. A grid **99** is mounted around the hot cathode for filtering and tube current control.

In the embodiment of FIGURES 3, 4, and 5, the housing **A** is again toroidal. The anode **B** is again annular and defines a cooling path **12** with a portion of the housing. The tungsten anode face **10** is disposed toward the cathode assembly **C** to generate the x-ray beam when excited by an electron beam from the cathode. The cathode assembly includes a multiplicity of cathode cups **100** arranged closely adjacent to each other in a ring around the housing. Each cathode cup includes a cathode filament **102** which is heated by an excitation current to undergo thermionic emission. A grid assembly includes a pair of grids **104** for focusing the generated electron beam in a circumferential direction relative to the anode and a pair of grids **106** for focusing the electron beam in a radial direction. A gate electrode **108** selectively permits and prevents the electron beam from reaching the anode. In the preferred embodiment, a switching means **110** sequentially switches each of the gate grids **108** to permit the passage of electrons. In this manner, the electron beam is stepped, or moved in other selected patterns, around the anode.

A biasing and focusing control circuit **112** applies appropriate bias voltages to the grid pairs **104**, **106** to focus the electron beam at a selected point on the anode relative to the cathode cup with a selected beam dimension. Optionally, the biasing and focusing control circuit **112** may include a scanning means **114** for gradually or incrementally shifting the bias voltage between the grids **104**, **106** to sweep or scan the electron beam continuously or in a plurality of steps to a plurality of positions along an arc segment of the anode commensurate with a circumferential length of the cathode cup. Each time the switching means **110** switches to the next cathode cup, it causes the beam scanning means **114** to sweep the electron beam along each of its preselected circumferential beam positions.

A high voltage means **120** biases the cathode assembly **C** to a high voltage relative to the housing. A ceramic insulation layer **122** insulates the cathode cups from the housing such that the cathode cups can be maintained at a potential, on the order of -130 kV, relative to the housing. For operator safety, the housing is preferably held to ground and the cathode cups are biased on the order of -130 kV relative to the housing and the anode. Alternately, the anode may be electrically insulated from the housing and biased to a positive voltage relative to the housing. In such an embodiment, care must be taken that the cooling fluid is dielectric such that the cooling fluid does not short the anode to the housing.

The filaments of all the cathode cups are preferably driven concurrently. The switching means **110** further switches the high voltage supply **120** sequentially to each of the cathode cups **100**. In this manner, only one or a small group of cathode cups at time is maintained at a sufficiently high voltage relative to the anode to cause an x-ray beam and the generation of x-rays. Of

course, either the grid **108** or the individual cathode cup biasing may be used individually to control the electron and x-ray beams. An x-ray beam apex location means **124** determines the location of the electron beam on the anode, hence the origin of the x-ray beam, from the output of switching means **110**.

Each individual cathode segment or cup preferably is constructed with radial slots with series or parallel connected filaments in each slot. Such slot and filament portions naturally provide line focus electron beams desirable for target loading when the grid voltage is removed from the desired segment. This radially slotted section may be divided in half and appropriately insulated to facilitate sweeping the focal spot across the anode track. These halves can also be used to alter the size of the focal spot.

An additional refinement may be obtained by heating the filament or, more generally, the electron emitter by a second cathode structure behind the emitter and accelerated by a more modest potential and a locally controlled grid in a similar manner to the main cathode structure. One of the benefits achieved by this construction is that low temperature, low work function filaments may be employed. This lowers the heating current requirement substantially. The electron emitters can be heated very uniformly to achieve a very uniform focal spot. These emitters furthermore may be constructed of tungsten ribbon or other suitable shaped material of low effective thermal mass so that an emitter may be boosted to operating temperature very quickly, requiring only grid control of the second filament to achieve markedly lower heating energy to the electron emitter and a large increase in reliability.

With reference again to FIGURES 1 and 2 which refer to examples not covered by the claims, a ring of detectors **130** are supported with a housing such that they remain stationary as the cathode assembly **C** rotates. A collimator or other off-focal radiation limiting means **132** is positioned relative to the point at which the electron beam impacts the anode such that the resultant collimated radiation beam **22** is incident on the detectors. The detectors are positioned as close as possible to the collimator such that the fan beam of radiation is, as close as possible, orthogonal to the central axis **24** of the ring tube. For ring tubes with an internal bore large enough to receive the human torso and an x-ray beam on the order of a millimeter thick, the x-ray beam can be defined by collimation to within a half a degree or less of orthogonal to the central axis. Preferably, the patient and the x-ray source move relative to each other along the central axis **24** such that the detected radiation data represents generally a spiral pattern through the patient. A conventional volume imaging means **134** reconstructs the spiral data from the detectors using the beam apex location information into a three-dimensional image representation which is stored in a volume image memory **136**. In spiral imaging, it will be appreciated that the continuous axial movement causes each sampling of the detectors to be in a different axial position, i.e. in a different plane. The adjustments made by the conventional volume imaging means **134** to interpolate the spiral data into parallel plane data for reconstruction can also make an appropriate adjustment for the angular offset between the axis and the x-ray beam. Optionally, a cone beam algorithm is used along with the interpolation of data. In single slice imaging, an analogous correction can be made. Alternately, because the angle is so small, the image can be reconstructed using conventional planar image reconstruction algorithms without compensating for the effective increase in the width of the slice.

The operator console **82** contains appropriate controls for withdrawing selected portions of the volume image representation from the volume image memory **136** for display on a video monitor **138** or other appropriate displays. As is conventional in the art, the operator control means **84** may select planes along orthogonal axes through the volume image data, planes skewed to the orthogonal axes, 3D type images with appropriate surface shading to provide the two-dimensional display with the appearance of three dimensions, and the like.

A shutter **140** is mounted for selective movement between a closed position covering the window and an open position which permits the transmission of x-rays through the window to the detector ring. The shutter ring is constructed of a radiation blocking material such that no radiation is permitted to pass therethrough when the shutter is closed. A shutter control means **142** such as a plurality of linear motors selectively slides the shutter ring between open and closed positions.

In the example of FIGURE 6, not covered by the claims, the collimator or off-focal radiation limiting means **132** defines the x-ray beam **22** perpendicular to the central axis **24**. The ring of radiation detectors **130** is fixed against rotation. A nutating means **144** moves the portion of the radiation detectors generally parallel to the central axis **24** such that the detectors are positioned in front of the window **20** opposite the apex location of the radiation beam. That portion of the detector ring which is positioned adjacent the point at which x-rays are being generated is offset from the plane of the x-ray beam such that the x-ray beam does not pass through those detectors.

In the illustrated embodiment, the nutating means **144** includes a wobble-plate type construction. More specifically, an annular motor **146** rotates an annular cam surface **148** which is mounted at an angle to the central axis **24**. As the angled plate or cam surface rotates, it rotates the portion of the detector ring which is cammed into alignment with the x-ray beam. Optionally, other devices can be provided for nutating the detector ring. For example, the detector ring can be made in segments which are moved parallel to the central axis **24** into and out of the plane of the x-ray beam. As another example, magnetic cams are used to produce the nutating movement.

In the alternate example of FIGURE 7, not covered by the claims, the x-ray beam is directed and collimated at a slight angle to the central axis **24** to impact a detector ring located near the exterior diameter of the ring tube. A plurality of cathode cups **32a** and **32b** are provided. Grids **36** filter, gate, and control the emitted electron beam. The cathode assembly is illustrated as being suspended by repulsive interaction with permanent magnets **42'** rather than attractive interaction with fields induced in the silicon iron hoops.

In the embodiment of FIGURE 8, a large diameter annular motor **150** rotates a partial ring of x-ray detectors **130'**. Optionally, a collimator, filter, or compensating means **152** may be mounted to rotate opposite the detector arc. A first angular position detecting means **58**, preferably a laser gyro, detects the angular position of the cathode assembly **B**. A second angular position detecting means **154** detects the angular position of the detector arc. A rotation controller **156** controls the operation of the motor **150** in accordance with the input from the two position detectors such that the detector arc rotates at precisely the same speed as the x-ray beam.

In the embodiment of FIGURE 9, the x-ray detector means **130** includes an arc of scintillation crystals **160** and a ring of opto-electrical transducers, such as photodiodes **162**. At least the scintillation crystal or other x-ray to light transducer means is mounted along an arc segment to the cathode assembly **C** opposite one or more cathode filaments. As the cathode assembly rotates, the arc of scintillation crystals rotates therewith. The photodiodes are mounted stationarily on the exterior of the housing. An optical coupling **164** transfers light from the rotating scintillation crystals to the stationary photodiodes as the cathode assembly rotates. A light amplifier is advantageously positioned between the scintillation crystals and the photodiodes. In the preferred embodiment, the scintillation crystals extend along only an arc segment such that the radiation does need to pass through the scintillation crystals before striking the patient. In areas beyond the scintillation crystal arc, a shielding means or ring **166** is provided for shielding the optical transfer means **164** for receiving light or other incident radiation.

With reference again to FIGURE 1, the mounting means **II** includes a rotating means **170** for selectively rotating the ring tube **I** about a horizontal axis. A vertical translating means **172** selectively translates the ring tube along a vertical axis. It is to be appreciated, that the rotating means can position the ring tube horizontally such that the vertical translating means **172** translates the ring tube along a standing patient. This enables patients to be imaged in a standing orientation to reflect the natural effects of gravity on the patient's body.

A horizontal translating means **174** selectively translates the ring tube along a horizontal direction. When the rotating means **170** positions the ring tube in a vertical position, the horizontal translating means can translate the ring tube along a stationary patient in a prone position, e.g. supported on a patient couch **176**. Optionally, the couch **176** includes a horizontal translating means **178** for moving a top surface of the couch, hence the patient, along a horizontal axis.

The electronic section **III** further includes means for causing the ring tube to generate a dual or multiple energy x-ray beam. In the embodiment of FIGURE 5, the dual or multiple energy means includes a grid potential modulating means **180**, such as an oscillating voltage source, for oscillating the potential applied to the gating grid of the active electron source. By modulating the gate potential voltage, the flow of electrons, hence the energy of the electron beam is selectively modulated.

In the embodiment of FIGURE 2, the dual energy means can include high and low energy electron sources disposed alternately around the cathode ring. As yet another alternative, each cathode cup **100** can include a second, lower energy filament. As yet another alternative, a grid is disposed around the hot cathode **92** to control the flow of energy to the cathode.

A pilot scan means **184** selectively gates each of the electron sources to emit an electron beam as it passes a preselected point on the anode, typically top dead center. This causes a fixed orientation x-ray beam to be generated for use in pilot scans. Preferably, the patient couch translating means **178** has a variable horizontal translation speed such that each gating of an electrode beam from the preselected point on the anode occurs in preselected steps along the patient.

With reference again to FIGURE 2, a plurality of lasers **186** are mounted on the shutter. The lasers emit beams of optically visible light in the plane of the window **20** for providing a visual indication of where the slice will be taken to the operator.

Claims

1. A CT scanner comprising:

   a generally toroidal x-ray tube (I) defining a central bore (26) of sufficient diameter for passing an imaged region of a subject therethrough, the toroidal x-ray tube generating a generally fan-shaped x-ray beam from a multiplicity of locations there around, which x-ray beam is directed across the central bore (26) from an apex location in the x-ray tube (I), said x-ray tube (I) including a generally toroidal housing (A) having an evacuated interior, an annular anode surface (10) mounted within the toroidal housing interior, a cathode assembly (C) disposed within the toroidal housing (A) including a means (100,102) for emitting electrons to form an electron beam that strikes the anode surface, and a means (D) for moving the electron beam to at least a multiplicity of points around the anode surface (10);

an x-ray tube mounting means (II) for mounting the toroidal x-ray tube;

a radiation detection means (130) including an arc of radiation detectors (130) spanning an arc for detecting the x-ray beam after it is passed through the imaged subject region in the bore (26);

an x-ray beam apex location determining means (124) for determining an angular position of the x-ray beam apex location; and

an image reconstruction means (134) operatively connected with the radiation detection means and the x-ray beam apex location determining means (124) for reconstructing an image representation of the image region of the subject,

characterized in that the radiation detection means includes:

a rotatable mounting means for mounting the arc of radiation detectors for rotation around the bore (26) of the toroidal x-ray tube;

a detector arc rotating means (150) for rotating the detector arc around the bore (26); and

a detector rotation control means (156) operatively connected with at least the x-ray beam apex location determining means (124) for controlling the detector arc rotating means such that the detector arc is maintained generally opposite to the determined apex location.

2. A CT scanner as claimed in claim 1, wherein said anode surface is in thermal communication with a cooling fluid passage (12) for circulating cooling fluid contiguous to the anode surface for removing heat therefrom.

3. A CT scanner as claimed in claim 1 or 2, wherein the x-ray tube further includes:

a rotatable mounting means (30,40) for rotatably mounting the cathcode assembly within the toroidal housing; and,

wherein the electron beam moving means (D) includes a means (50) for rotating the cathode assembly.

4. A CT scanner as claimed in claim 3, wherein the x-ray tube further includes:

a compensator (62) mounted to the cathode assembly adjacent the x-ray source such that the generated x-ray beam passes therethrough.

5. A CT scanner as claimed in claim 4, wherein the compensator (62) includes a beryllium oxide element.

6. A CT scanner as claimed in any one of the preceding claims, wherein the cathode assembly includes a multiplicity of electron emitting means (100,102) arranged in an annular ring (30) within the housing opposite the anode surface (10) and wherein the electron beam moving means includes a means for selectively causing each of the electron emitting means to emit a beam of electrons which impact the anode surface to generate the x-ray beam.

7. A CT scanner as claimed in any one of the preceding claims, wherein the housing (A) defines an annular window (20) facing toward a central axis of the toroidal housing bore (26) through which the x-ray beam passes and further including:

an annular shutter member (140) which is disposable across the window (20) for blocking the emission of radiation therefrom; and,

a means (142) for selectively moving the shutter member into and out of the radiation blocking relationship with the window (20).

8. A CT scanner as claimed in any one of the preceding claims, wherein the x-ray beam apex location determining means includes a laser gyro (58) for monitoring an angular position of the cathode assembly.

9. A CT scanner as claimed in any one of the preceding claims, wherein the radition detection means includes:

a plurality of scintillation crystal means (160) for converting received radiation into light, the scintillation crystal means being rotatably mounted to the toroidal x-ray tube for rotation around the central bore thereof;

a ring of opto-electrical transducers (162) for converting received light into corresponding electrical signals, the opto-electrical transducers being stationarily mounted with the toroidal housing in optical communication with the scintillation crystal means such that a corresponding fraction of the opto-electrical transducers are in optical communication with the arc of scintillation crystal means, the opto-electrical transducer being operatively connected with the image reconstruction means.

10. A CT scanner as claimed in any one of the preceding claims further including a means (180) for controlling the electron emitting means such that the x-ray beam generated by the electron beam striking

the anode surface has at least two different energies.

11. A CT scanner as claimed in any one of the preceding claims, wherein the electron emitting means (100,102) includes at least a high energy electron beam emitting means for emitting a beam of electrons which strikes the anode surface and forms a higher energy x-ray beam and a low energy electron beam emitting means for emitting an electron beam which strikes the anode surface and generates a lower energy x-ray beam.

12. A CT scanner as claimed in any one of the preceding claims further including a plurality of voltage sources (90) which are connected in parallel to apply a relatively high potential between the electron emitting means (100,102) and the anode surface, there being a sufficiently large plurality of voltage sources that if one of the voltage sources (90) fails, the remaining voltage sources provide sufficient electrical energy to continue generating the x-ray beam but at a reduced power.

13. A CT scanner as claimed in claim 12, wherein the voltage sources (90) are connected with a rechargeable electric power supply (93) which provides relatively high current during generation of the x-ray beam and draws a relatively low current to recharge.

14. A CT scanner as claimed in any one of the preceding claims, wherein the toroidal x-ray tube mounting means (II) includes:

    a means (170) for selectively rotating the toroidal x-ray tube about a horizontal axis;
    a means (172) for selectively translating the toroidal x-ray tube vertically, whereby the CT scanner is adapted to reconstruct an image representation of a standing subject.

15. A CT scanner as claimed in any one of the preceding claims, wherein the x-ray tube mounting means (II) further includes a means (174) for translating the toroidal x-ray tube horizontally.

16. A CT scanner as claimed in any one of the preceding claims, wherein the image reconstruction means includes:

    a volume imager (134) for reconstructing a three-dimensional image representation of an examined region of the subject;
    an operator control panel (138) for selectively controlling the retrieval and display of two-dimensional representations of portions of the three-dimensional image representation.

Patentansprüche

1. CT-Scanner, umfassend:

    eine im allgemeinen ringförmige Röntgenröhre (I), die eine zentrale Bohrung (26) von ausreichendem Durchmesser zum Hindurchlaufen eines abzubildenden Bereiches eines Gegenstandes definiert, wobei die ringförmige Röntgenröhre einen im allgemeinen fächerförmigen Röntgenstrahl aus einer Vielzahl von umliegenden Orten erzeugt, wobei der Röntgenstrahl quer zu der zentralen Bohrung (26) von einem Scheitelort in der Röntgenröhre (I) aus gerichtet ist, wobei die Röntgenröhre (I) ein im allgemeinen ringförmiges Gehäuse (A), welches ein vakuumisiertes Inneres hat, eine Winkelanodenoberfläche (10), die innerhalb des ringförmigen Gehäuseinneren befestigt ist, ein Kathodenzusammenbau (C), der innerhalb des ringförmigen Gehäuses (A) angeordnet ist, welcher eine Einrichtung (100, 102) zum Emittieren von Elektronen beinhaltet, um einen Elektronenstrahl zu bilden, der auf die Anodenoberfläche auftrifft, und eine Einrichtung (D) zum Bewegen des Elektronenstrahls auf zumindest eine Vielzahl von Punkten um die Anodenoberfläche (10) herum, beinhaltet;
    eine Röntgenröhren-Befestigungseinrichtung (II) zum Befestigen der ringförmigen Röntgenröhre;
    eine Strahlungsdetektionseinrichtung (130), die einen Bogen von Strahlungsdetektoren (130) beinhaltet, welche einen Bogen zum Detektieren des Röntgenstrahls aufspannt, nachdem er durch den abzubildenden Gegenstandsbereich in der Bohrung (26) hindurchgelaufen ist;
    eine Bestimmungseinrichtung (124) für einen Röntgenstrahl-Scheitelort, zum Bestimmen einer Winkelposition des Röntgenstrahl-Scheitelortes; und
    eine Bildwiederherstellungseinrichtung (134), die betrieblich mit der Strahlungsdetektionseinrichtung und der Bestimmungseinrichtung (124) für den Röntgenstrahl-Scheitelort zum Wiederherstellen einer Bilddarstellung des Abbildungsbereiches des Gegenstandes verbunden ist,
    dadurch gekennzeichnet, daß
    die Strahlungsdetektionseinrichtung beinhaltet:

        eine drehbare Befestigungseinrichtung zum Befestigen des Bogens der Strahlungsdetektoren, um sie um die Bohrung (126) der ringförmigen Röntgenröhre herum zu drehen;
        eine Dreheinrichtung (150) für den Detek-

torbogen zum Drehen des Detektorbogens um die Bohrung (26) herum; und

eine Steuerungseinrichtung (156) für die Detektordrehung, welche betrieblich mit mindestens der Bestimmungseinrichtung (124) für den Röntgenstrahl-Scheitelort verbunden ist, zum Steuern der Dreheinrichtung des Detektorbogens, so daß der Detektorbogen im allgemeinen gegenüberliegend zu dem bestimmten Scheitelort gehalten wird.

2. CT-Scanner nach Anspruch 1, worin die Anodenoberfläche in thermischer Verbindung mit einem Abkühlungs-Fluiddurchlauf (12) zum Zirkulieren eines Abkühlungsfluids benachbart zu der Anodenoberfläche ist, um die Wärme davon zu entfernen.

3. CT-Scanner nach Anspruch 1 oder 2, worin die Röntgenröhre weiterhin beinhaltet:

   eine drehbare Befestigungseinrichtung (30, 40) zum drehbaren Befestigen des Kathodenzusammenbaus innerhalb des ringförmigen Gehäuses; und

   worin die Elektronenstrahl-Bewegungseinrichtung (D) eine Einrichtung (50) zum Drehen des Kathodenzusammenbaus beinhaltet.

4. CT-Scanner nach Anspruch 3, worin die Röntgenröhre weiterhin beinhaltet:

   einen Kompensator (62), der mit dem Kathodenzusammenbau benachbart zu der Röntgenstrahlquelle verbunden ist, so daß der erzeugte Röntgenstrahl dort hindurchläuft.

5. CT-Scanner nach Anspruch 4, worin der Kompensator (62) ein Berylliumoxid-Element beinhaltet.

6. CT-Scanner nach einem der vorangegangenen Ansprüche, worin der Kathodenzusammenbau eine Vielzahl von Elektronen emittierenden Einrichtungen (100, 102) beinhaltet, die in einer Ringwulst (30) innerhalb des Gehäuses gegenüber der Anodenoberfläche (100) angeordnet sind und worin die Bewegungseinrichtung des Elektronenstrahls eine Einrichtung zum selektiven Veranlassen der einzelnen Elektronen emittierenden Einrichtungen beinhaltet, einen Strahl von Elektronen, die auf die Anodenoberfläche auftreffen um einen Röntgenstrahl zu erzeugen, zu emittieren.

7. CT-Scanner nach einem der vorangegangenen Ansprüche, worin das Gehäuse (A) ein ringförmges Fenster (20) definiert, welches in Richtung auf eine zentrale Achse der ringförmigen Gehäusebohrung (26) gerichtet ist, durch welche der Röntgenstrahl hindurchläuft und welches weiterhin beinhaltet:

   ein ringförmiges Schließteil (140) , welches quer zu dem Fenster (20) zum Blockieren der Strahlungsemission, die aus diesem kommt, anordenbar ist; und

   eine Einrichtung (142) zum selektiven Bewegen des Schließteiles in und aus der Strahlungsblockierungsbeziehung zu dem Fenster (20).

8. CT-Scanner nach einem der vorangegangenen Ansprüche, worin die Bestimmungseinrichtung des Röntgenstrahl-Scheitelortes einen Laserkreisel (58) zum Überwachen einer Winkelposition des Kathodenzusammenbaus beinhaltet.

9. CT-Scanner nach einem der vorangegangenen Ansprüche, worin die Strahlungsdetektionseinrichtung beinhaltet:

   eine Vielzahl von Szintillations-Kristalleinrichtungen (160) zum Umwandeln der empfangenen Strahlung in Licht, wobei die Szintillations-Kristalleinrichtungen drehbar an der ringförmigen Röntgenröhre zur Drehung um ihre zentrale Bohrung herum befestigt sind;

   ein Ring von opto-elektrischen Umwandlern (162) zum Umwandeln von empfangenem Licht in korrespondierende elektrische Signale, wobei der opto-elektrische Umwandler stationär mit dem ringförmigen Gehäuse in optischer Verbindung mit den Szintillations-Kristalleinrichtungen verbunden ist, so daß ein korrespondierender Bruchteil des opto-elektrischen Umwandlers in optischer Verbindung mit dem Bogen der Szintillations-Kristalleinrichtungen ist, wobei der opto-elektrische Umwandler betrieblich mit der Bildwiederherstellungseinrichtung verbunden ist.

10. CT-Scanner nach einem der vorangegangenen Ansprüche, weiterhin eine Einrichtung (180) zum Steuern der Elektronen emittierenden Einrichtung beinhaltend, so daß die Röntgenstrahlen, die durch den Elektronenstrahl erzeugt werden, welcher auf die Anodenoberfläche auftrifft, mindestens zwei verschiedene Energien haben.

11. CT-Scanner nach einem der vorangegangenen Ansprüche, worin die Elektronen emittierenden Einrichtungen (100, 102) mindestens eine emittierende Einrichtung für Hochenergie-Elektronenstrahlen zum Emittieren eines Strahles von Elektronen, welche auf die Anodenoberfläche auftreffen und einen Röntgenstrahl mit höherer Energie bilden und eine emittierende Einrichtung für Elektronenstrahlen mit niedriger Energie zum

Emittieren eines Elektronenstrahles, welcher auf die Anodenoberfläche auftrifft und einen Röntgenstrahl mit niedriger Energie erzeugt, beinhalten.

12. CT-Scanner nach einem der vorangegangenen Ansprüche, weiterhin eine Vielzahl von Spannungsquellen (90) beinhaltend, welche parallel verbunden sind, um ein relativ hohes Potential zwischen den Elektronen emittierenden Einrichtungen (100, 102) und der Anodenoberfläche aufzubringen, wobei es eine ausreichend große Zahl an Spannungsquellen gibt, die, wenn eine der Spannungsquellen (90) gestört ist, die verbleibenden Spannungsquellen die ausreichende elektrische Energie liefern läßt, um kontinuierlich den Röntgenstrahl zu erzeugen, jedoch bei einer reduzierten Leistung.

13. CT-Scanner nach Anspruch 12, worin die Spannungsquellen (90) mit einer wiederaufladbaren elektrischen Stromversorgung (93) verbunden sind, welche einen relativ hohen Strom während der Erzeugung des Röntgenstrahles liefert und welche einen relativ niedrigen Strom zum Wiederaufladen aufnimmt.

14. CT-Scanner nach einem der vorangegangenen Ansprüche, worin die ringförmige Befestigungseinrichtung (II) der Röntgenröhre beinhaltet:

    eine Einrichtung (170) zum selektiven Drehen der ringförmigen Röntgenröhre um eine horizontale Achse;
    eine Einrichtung (172) zum selektiven vertikalen Übertragen der ringförmigen Röntgenröhre, wodurch der CT-Scanner dazu geeignet ist, eine Bilddarstellung eines stehenden Gegenstandes wiederherzustellen.

15. CT-Scanner nach einem der vorangegangenen Ansprüche, Worin die Befestigungseinrichtung (II) der Röntgenröhre weiterhin eine Einrichtung (174) zum horizontalen Übertragen der ringförmigen Röntgenröhre beinhaltet.

16. CT-Scanner nach einem der vorangegangenen Ansprüche, worin die Bildwiederherstellungseinrichtung beinhaltet:

    ein Volumen-Abbildungsgerät (134) zum Wiederherstellen einer dreidimensionalen Bilddarstellung eines geprüften Bereiches des Gegenstandes;
    ein Bedienungs-Steuerungspult (138) zum selektiven Steuern der Wiedergewinnung und des Anzeigens von zweidimensionalen Darstellungen der Anteile der dreidimensionalen Bilddarstellung.

Revendications

1. Scanographe comprenant :

    un tube radiographique (I) de forme générale toroïdale délimitant un trou central (26) de diamètre suffisant pour le passage d'une région d'un sujet dont l'image doit être formée, le tube toroïdal à rayons X créant un faisceau de rayons X ayant une forme générale en éventail à partir de plusieurs emplacements environnants, le faisceau de rayons X étant dirigé transversalement au trou central (26) depuis l'emplacement d'un sommet à l'intérieur du tube à rayons X (I), le tube à rayons X (I) comprenant un boîtier de forme générale toroïdale (A) dont l'intérieur est sous vide, une surface anodique annulaire (10) montée à l'intérieur du boîtier toroïdal, un ensemble à cathode (C) placé à l'intérieur du boîtier toroïdal (A) et comprenant un dispositif (100, 102) destiné à émettre des électrons pour la formation d'un faisceau d'électrons qui vient frapper la surface de l'anode, et un dispositif (D) destiné à déplacer le faisceau d'électrons en au moins de nombreux points autour de la surface de l'anode (10),
    un dispositif (II) de montage de tubes à rayons X destiné au montage du tube toroïdal à rayons X,
    un dispositif (130) de détection de rayonnement comprenant un arc de détecteurs de rayonnement (130) recouvrant un arc de détection du faisceau de rayons X après son passage à travers la région du sujet dont l'image doit être formée et qui se trouve dans le trou (26),
    un dispositif (124) de détermination de l'emplacement du sommet du faisceau de rayons X destiné à déterminer la position angulaire de l'emplacement du sommet du faisceau de rayons X, et
    un dispositif (134) de reconstruction d'image raccordé pendant le fonctionnement au dispositif de détection du rayonnement et au dispositif (124) de détermination de l'emplacement du sommet du faisceau de rayons X pour la reconstruction d'une représentation d'image de la région du sujet dont l'image doit être formée,
    caractérisé en ce que le dispositif de détection de rayonnement comprend :

        un dispositif rotatif de montage de l'arc des détecteurs de rayonnement afin qu'il tourne autour du trou (26) du tube toroïdal à rayons X,
        un dispositif (150) destiné à faire tourner l'arc de détecteurs autour du trou (26), et

un dispositif (156) de commande de rotation de détecteurs connecté pendant le fonctionnement au moins au dispositif (124) de détermination d'emplacement du sommet du faisceau de rayons X pour la commande du dispositif d'entraînement en rotation de l'arc de détecteurs si bien que l'arc de détecteurs est maintenu de façon générale en face de l'emplacement du sommet déterminé.

2. Scanographe selon la revendication 1, dans lequel la surface de l'anode est en communication thermique avec un passage (12) de fluide de refroidissement destiné à faire circuler un fluide de refroidissement à un emplacement contigu à la surface de l'anode pour l'extraction de chaleur de celle-ci.

3. Scanographe selon la revendication 1 ou 2, dans lequel le tube à rayons X comporte en outre :

un dispositif rotatif de montage (30, 40) de l'ensemble cathodique à l'intérieur du boîtier toroïdal, et

le dispositif (D) de déplacement du faisceau d'électrons comporte un dispositif (50) destiné à faire tourner l'ensemble cathodique.

4. Scanographe selon la revendication 3, dans lequel le tube à rayons X comporte en outre

un compensateur (62) monté sur l'ensemble cathodique près de la source de rayons X afin que le faisceau créé de rayons X passe dans le compensateur.

5. Scanographe selon la revendication 4, dans lequel le compensateur (62) comporte un élément d'oxyde de béryllium.

6. Scanographe selon l'une quelconque des revendications précédentes, dans lequel l'ensemble cathodique comprend plusieurs dispositifs d'émission d'électrons (100, 102) disposés suivant un anneau (30) dans le boîtier en face de la surface de l'anode (10), et dans lequel le dispositif de déplacement du faisceau d'électrons comporte un dispositif destiné à provoquer l'émission sélective par chacun des dispositifs d'émission d'électrons d'un faisceau d'électrons qui tombe sur la surface de l'anode pour la création du faisceau de rayons X.

7. Scanographe selon l'une quelconque des revendications précédentes, dans lequel le boîtier (A) délimite une fenêtre annulaire (20) tournée vers l'axe central du trou (26) du boîtier toroïdal par lequel passe le faisceau de rayons X, et comprenant en outre :

un organe obturateur annulaire (140) qui peut être placé sur la fenêtre (20) pour l'arrêt de l'émission du rayonnement en provenant, et
un dispositif (142) destiné à déplacer sélectivement l'organe obturateur en position d'arrêt du rayonnement dans la fenêtre (20) et à distance de cette position.

8. Scanographe selon l'une quelconque des revendications précédentes, dans lequel le dispositif de détermination de l'emplacement du sommet du faisceau de rayons X comprend un gyroscope à laser (58) destiné à contrôler la position angulaire de l'ensemble cathodique.

9. Scanographe selon l'une quelconque des revendications précédentes, dans lequel le dispositif de détection de rayonnement comprend :

plusieurs dispositifs à cristaux à scintillation (160) destinés à transformer le rayonnement reçu en lumière, le dispositif à cristaux à scintillation étant monté afin qu'il puisse tourner sur le tube toroïdal à rayons X autour du trou central de celui-ci,
un anneau de transducteurs opto-électriques (162) destiné à transformer la lumière reçue en signaux électriques correspondants, les transducteurs opto-électriques étant montés de manière fixe sur le boîtier toroïdal en communication optique avec le dispositif à cristaux à scintillation afin qu'une fraction correspondante des transducteurs opto-électriques soit en communication optique avec l'arc du dispositif à cristaux à scintillation, les transducteurs opto-électriques étant connectés pendant le fonctionnement au dispositif de reconstruction d'image.

10. Scanographe selon l'une quelconque des revendications précédentes, comprenant en outre un dispositif (180) de commande du dispositif d'émission d'électrons afin que le faisceau de rayons X créé par le faisceau d'électrons frappant la surface anodique ait au moins deux énergies différentes.

11. Scanographe selon l'une quelconque des revendications précédentes, dans lequel le dispositif d'émission d'électrons (100, 102) comporte au moins un dispositif d'émission d'un faisceau d'électrons d'énergie élevée destiné à émettre un faisceau d'électrons qui frappe la surface de l'anode et forme un faisceau de rayons X d'énergie élevée et un dispositif d'émission d'un faisceau d'électrons de faible énergie destiné à émettre un faisceau d'électrons qui frappe la surface de l'anode et crée un

faisceau de rayons X de plus faible énergie.

12. Scanographe selon l'une quelconque des revendications précédentes, comprenant en outre plusieurs sources de tension (90) qui sont connectées en parallèle pour l'application d'un potentiel relativement élevé entre le dispositif d'émission d'électrons (100, 102) et la surface de l'anode, un nombre suffisamment grand de sources de tension étant incorporé pour que, si l'une des sources de tension (90) est en panne, les sources restantes de tension transmettent une quantité suffisante d'énergie électrique pour poursuivre la création du faisceau de rayons X, mais avec une puissance réduite.

13. Scanographe selon la revendication 12, dans lequel les sources de tension (90) sont connectées à une alimentation électrique rechargeable (93) qui transmet un courant relativement élevé pendant la création du faisceau de rayons X et qui consomme un courant relativement faible pour sa recharge.

14. Scanographe selon l'une quelconque des revendications précédentes, dans lequel le dispositif de montage (II) de tube toroïdal à rayons X comprend :

un dispositif (170) destiné à faire tourner sélectivement le tube toroïdal à rayons X autour d'un axe horizontal, et
un dispositif (172) destiné à déplacer sélectivement en translation le tube toroïdal à rayons X verticalement, si bien que le scanographe est destiné à reconstruire une représentation d'image d'un sujet debout.

15. Scanographe selon l'une quelconque des revendications précédentes, dans lequel le dispositif de montage (II) du tube à rayons X comporte en outre un dispositif (174) destiné à déplacer en translation horizontale le tube toroïdal à rayons X.

16. Scanographe selon l'une quelconque des revendications précédentes, dans lequel le dispositif de reconstruction d'image comprend :

un organe (134) de formation d'image de volume destiné à reconstruire une représentation d'image tridimensionnelle d'une région examinée du sujet, et
un panneau de commande (138) destiné à un opérateur et permettant la commande sélective de la récupération et de l'affichage de représentations bidimensionnelles de parties de la représentation d'image tridimensionnelle.

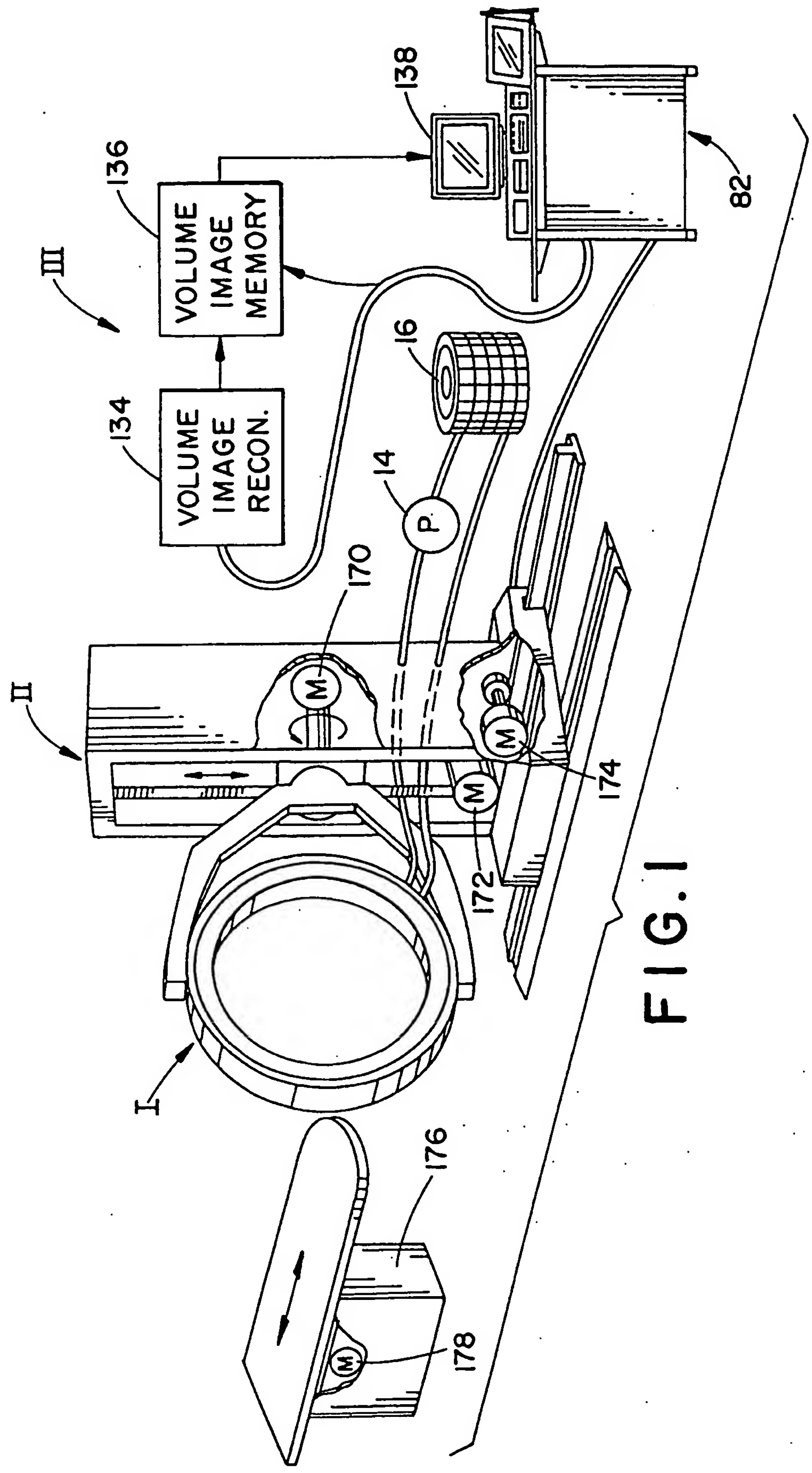

VOLUME IMAGE RECON.
VOLUME IMAGE MEMORY
134
136
138
III
II
I
82
16
14
P
170
172
174
176
178
M

FIG. 1

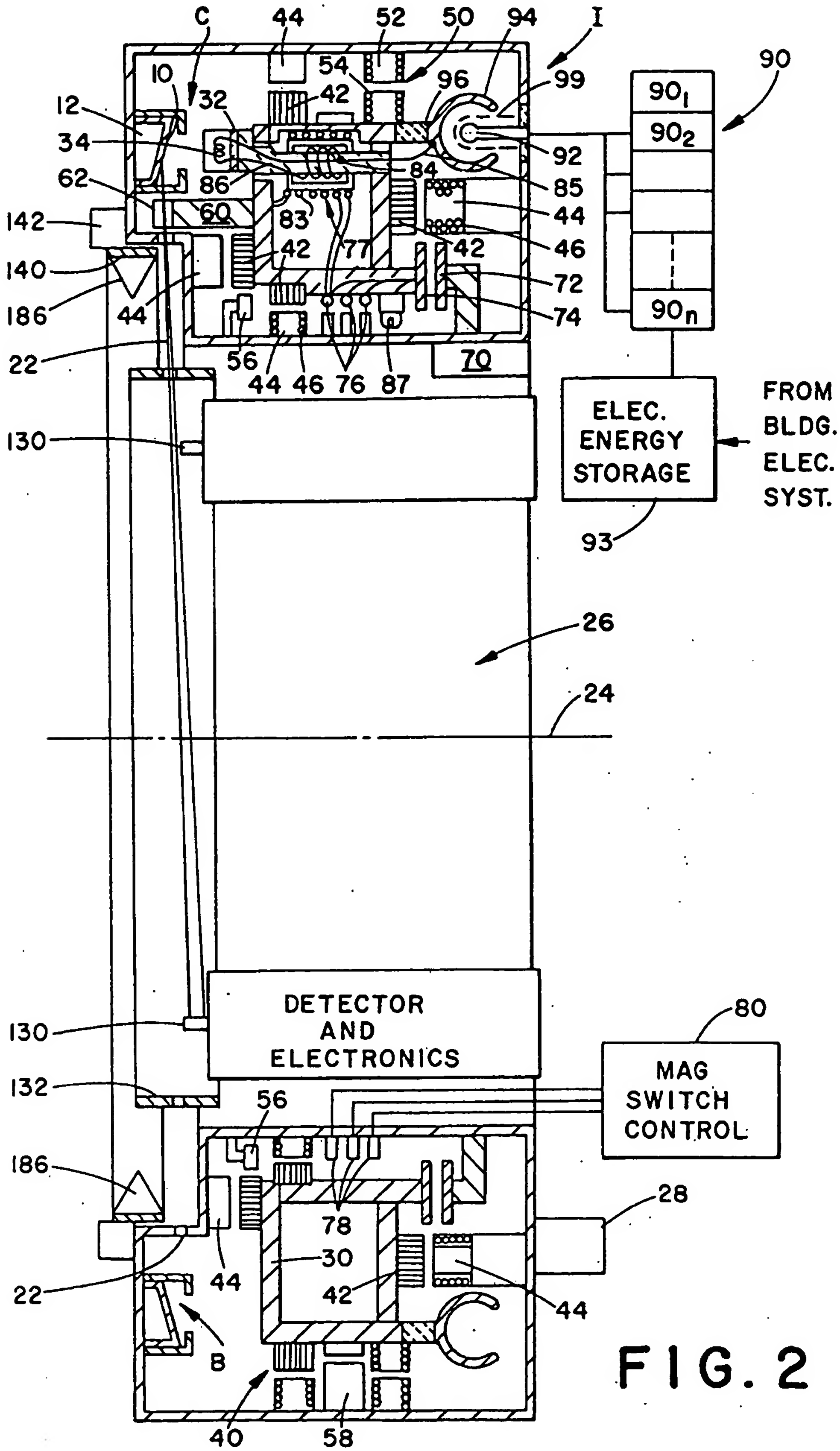

C
44
52
50
94
I
90
10
54
96
99
12
32
42
90₁
90₂
34
92
86
84
85
62
60
83
44
142
77
42
46
140
42
72
186
44
74
90ₙ
22
56
70
44 46 76 87
ELEC.
ENERGY
STORAGE
FROM
BLDG.
ELEC.
SYST.
130
93
26
24
DETECTOR
AND
ELECTRONICS
80
130
MAG
SWITCH
CONTROL
132
56
186
28
78
30
22
44
42
44
B
40
58

FIG. 2

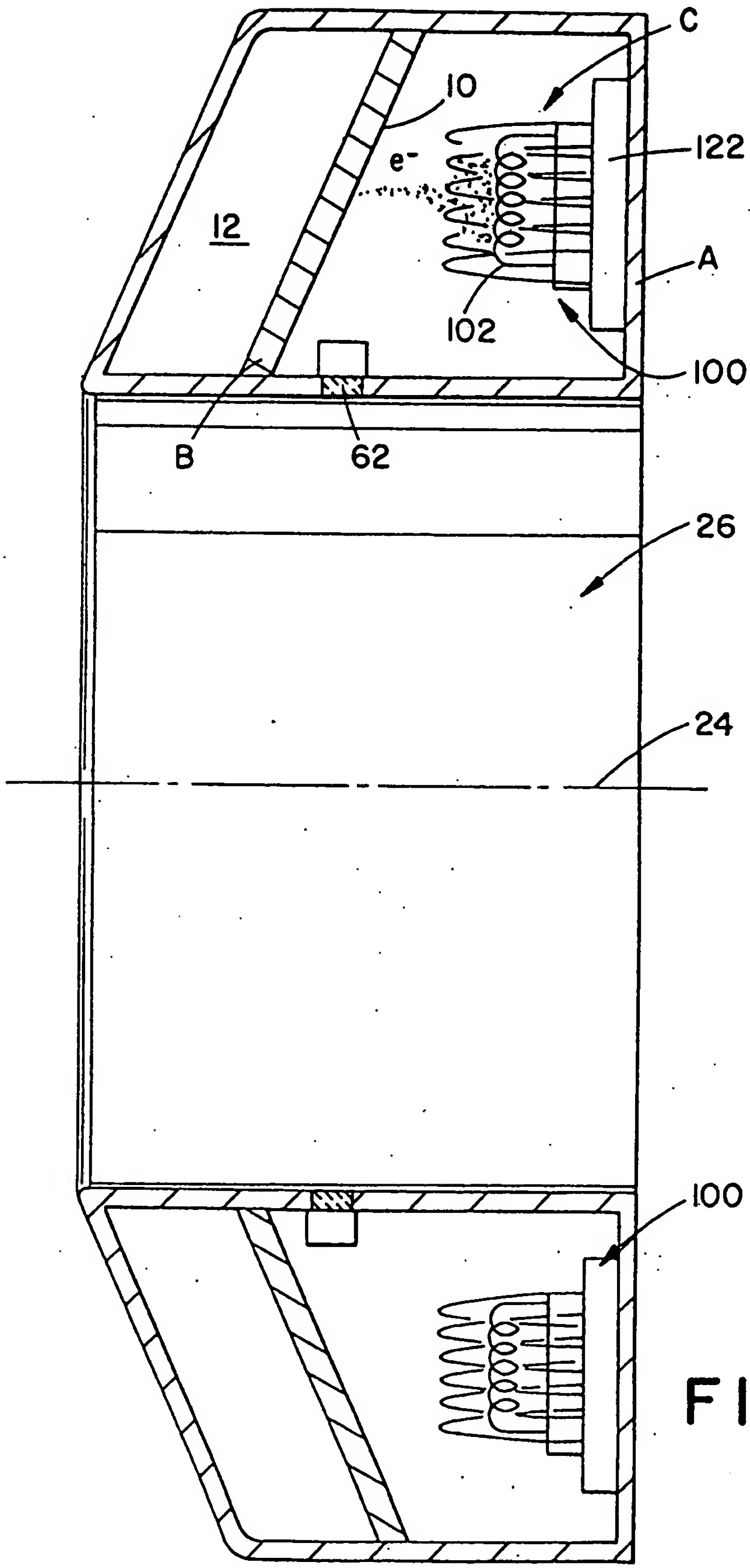


FIG. 3

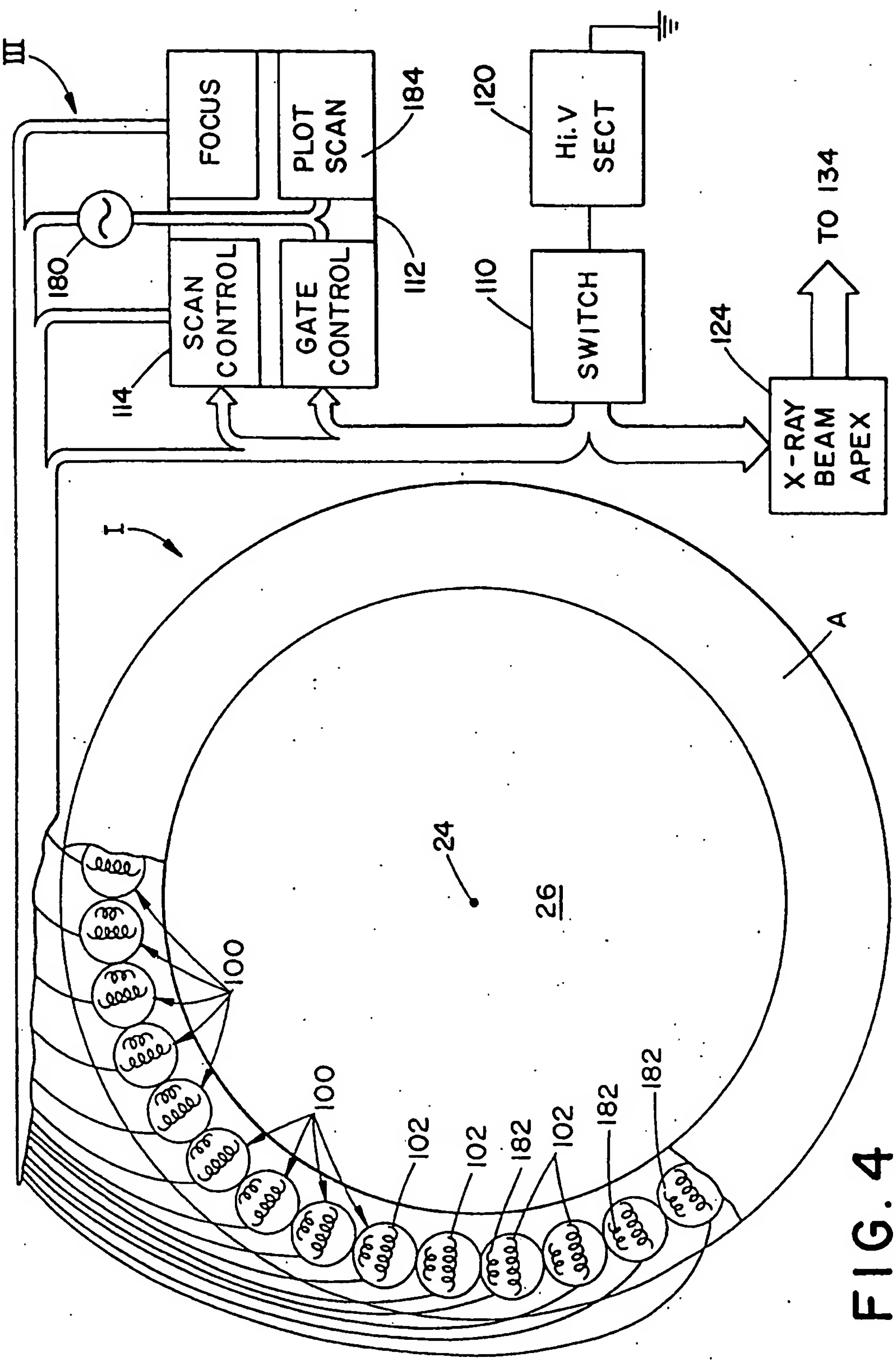

III
FOCUS
PLOT
SCAN
184
120
Hi. V
SECT
180
SCAN
CONTROL
GATE
CONTROL
112
110
SWITCH
TO 134
114
124
X-RAY
BEAM
APEX
I
A
24
26
100
100
102
102
182
102
182
182

FIG. 4

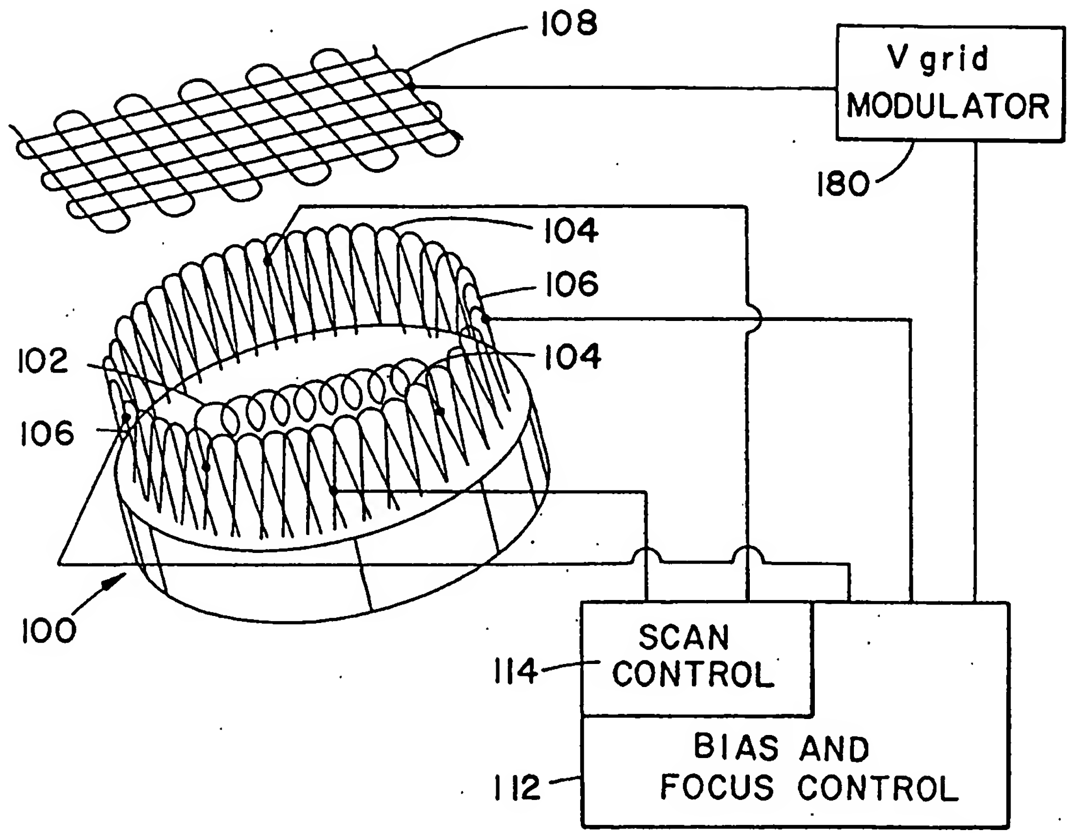

108
V grid
MODULATOR
180
104
106
102
104
106
100
SCAN
CONTROL
114
BIAS AND
FOCUS CONTROL
112

FIG. 5

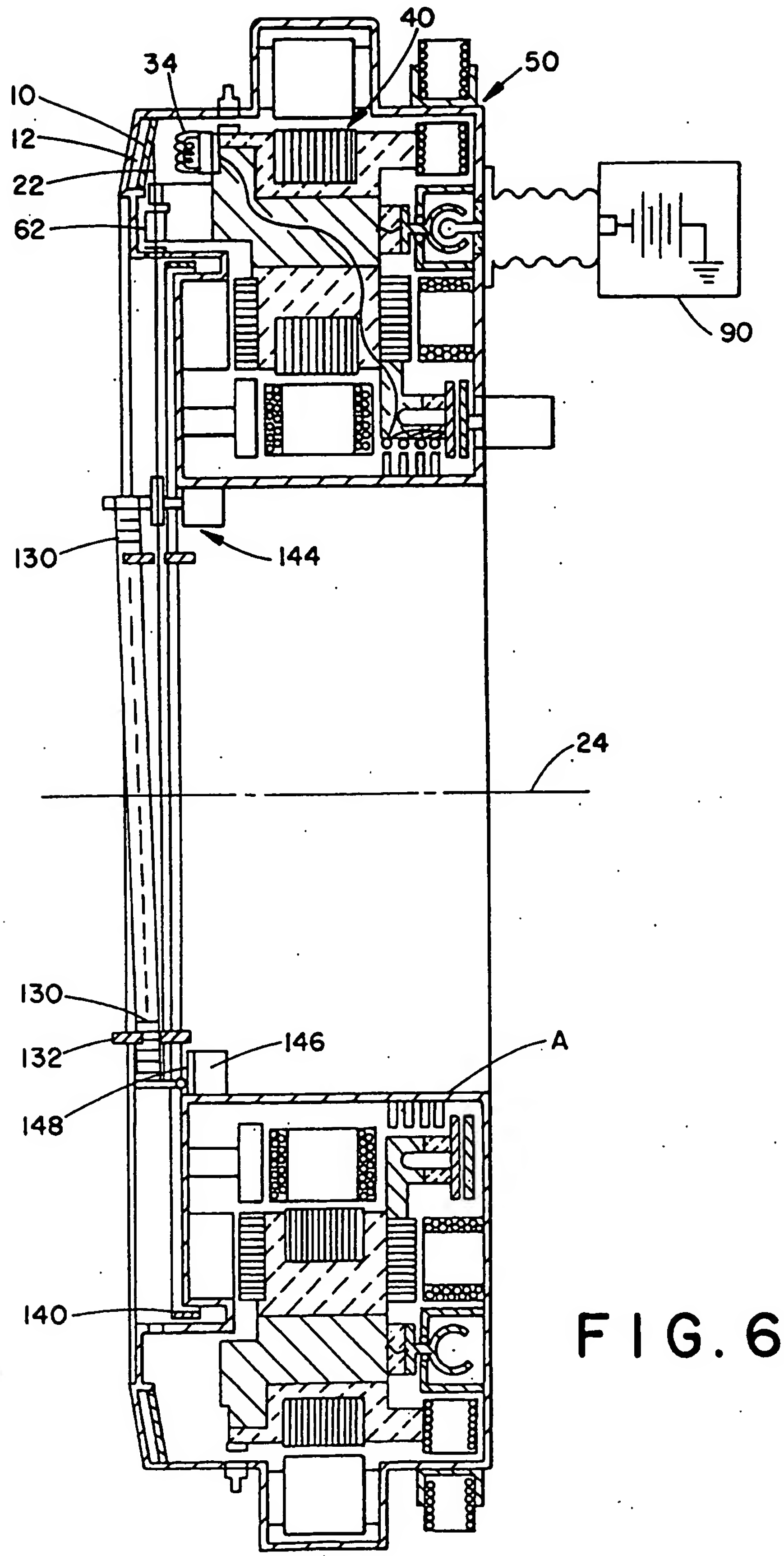
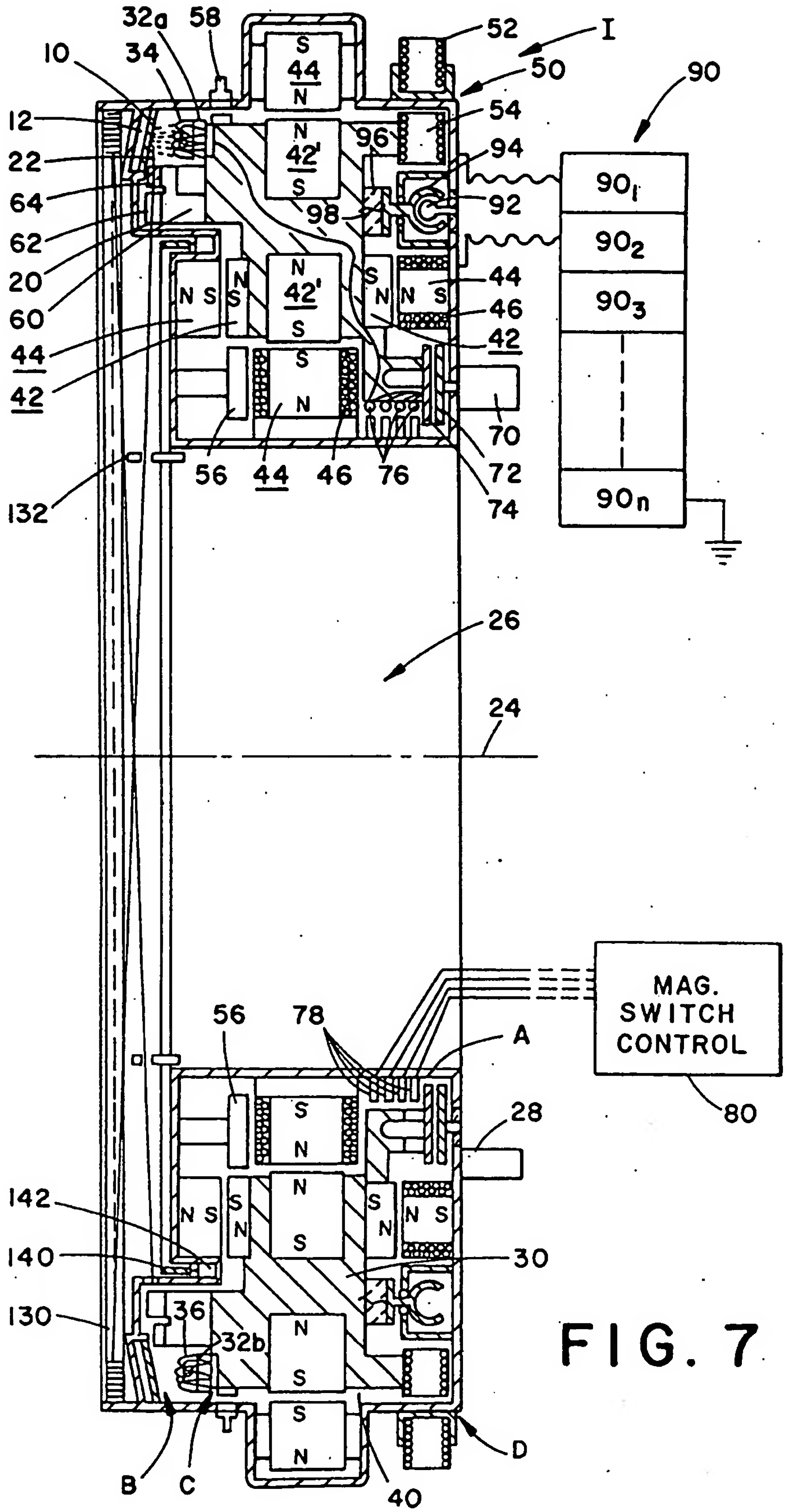


FIG. 6



I
10
12
22
64
62
20
60
44
42
32a
34
58
52
50
54
96
94
92
98
90
90₁
90₂
90₃
90n
46
70
72
74
76
56
132
26
24
MAG. SWITCH CONTROL
80
78
A
28
142
140
130
30
36
32b
B
C
40
D

FIG. 7

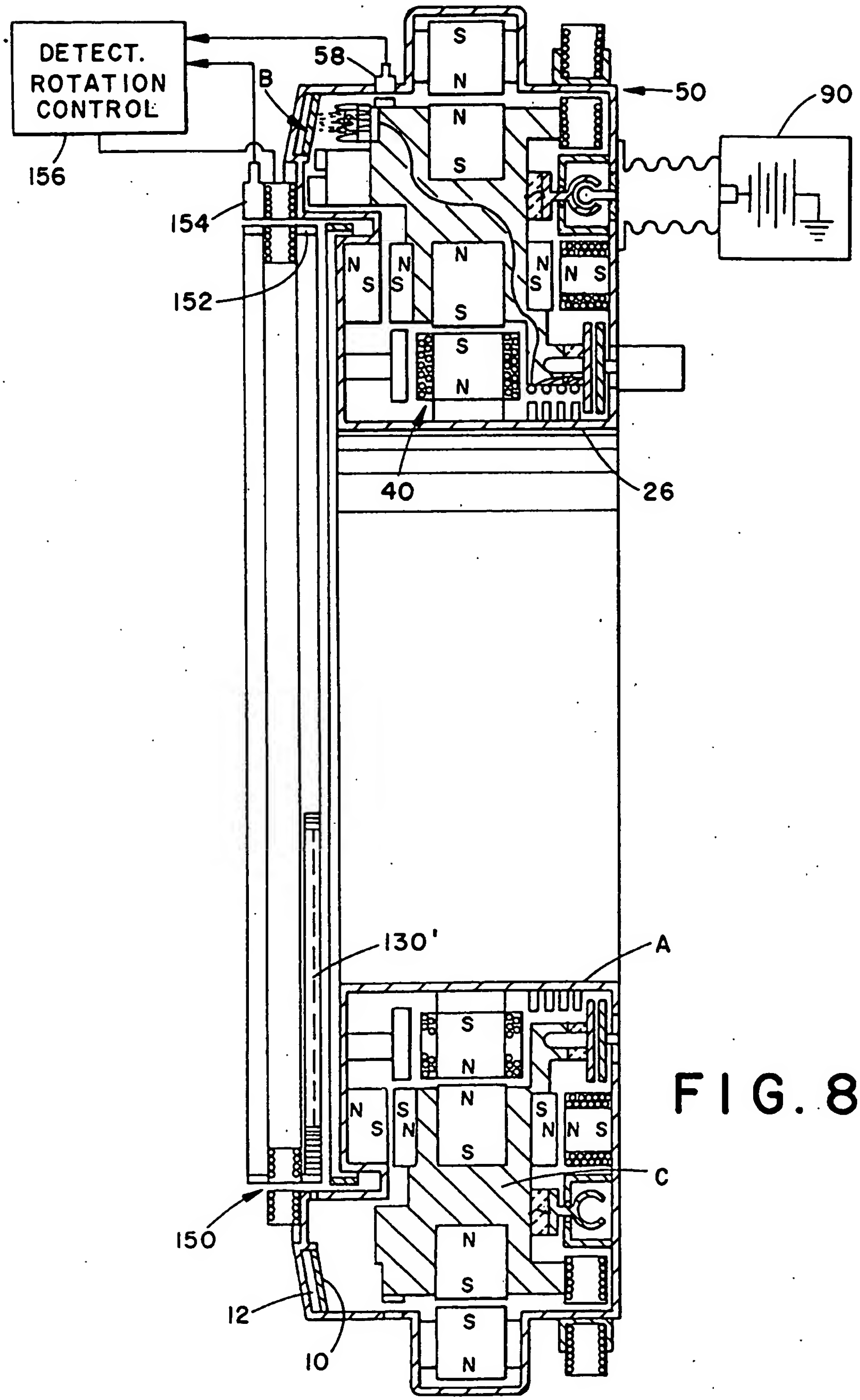

DETECT.
ROTATION
CONTROL
156
154
152
58
B
50
90
S
N
40
26
130'
A
C
150
12
10

FIG. 8

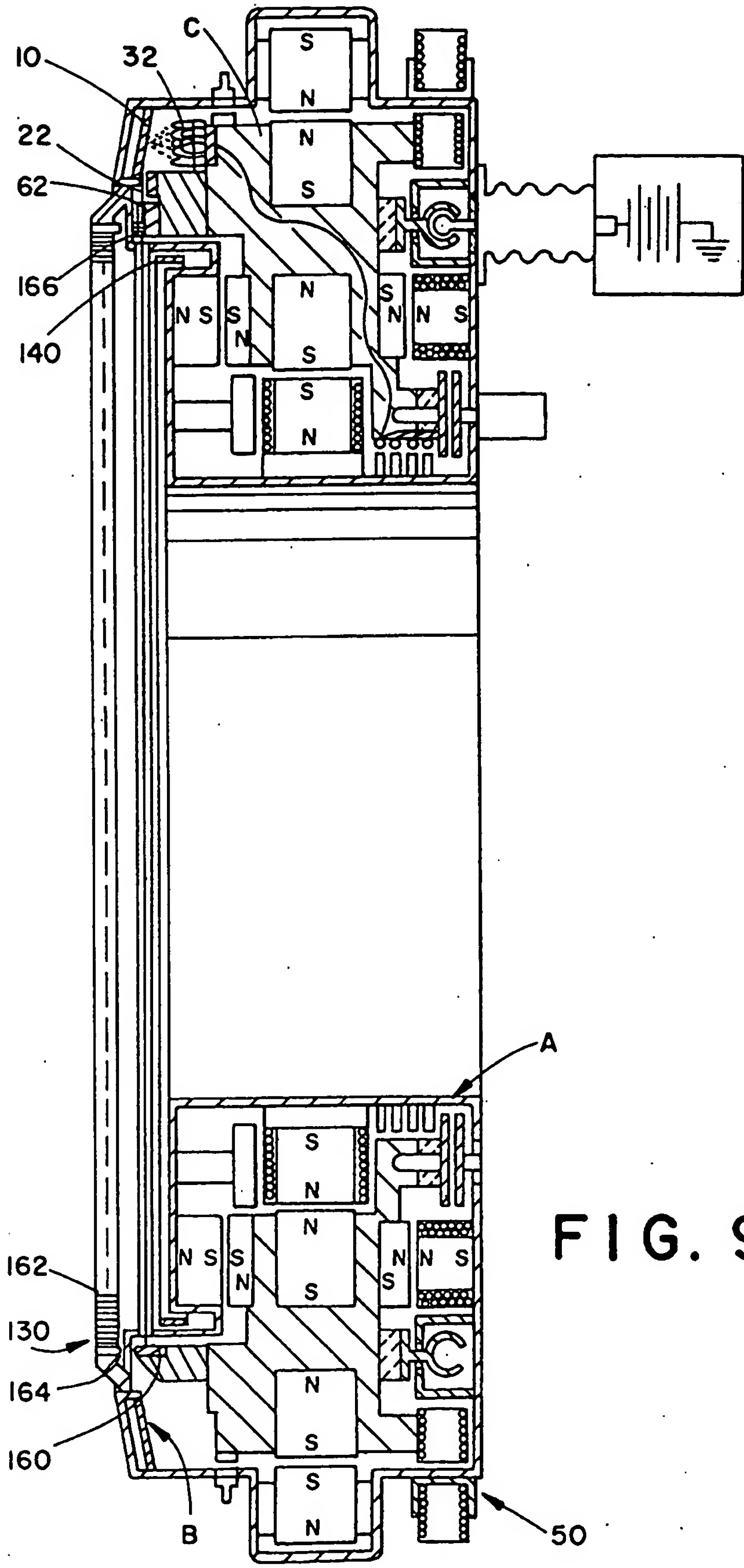

C
10
32
22
62
166
140
S
N
N
S
N S
S N
N
S
S N
N S
S
N
A
S
N
N S
S N
N
S
N S
N S
162
130
164
160
N
S
S
N
B
50

FIG. 9